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ABSTRACT

The Tillamook Digester is a fully operational demonstration project that will identify the components necessary to bring the concept to a financially viable alternative for handling waste manure from dairy operations in Tillamook County.

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EXECUTIVE SUMMARY

Viability of Tillamook County's dairy industry is critical to the local economy. Environmental restrictions on land application of raw manure have forced the industry to limit operations and herd size. In order for the industry to survive in a wet coastal climate, raw manure must be processed before field applications. To solve this problem, the Methane Energy Agricultural Development MEAD was formed with the dairy industry and local governments. The goal was to build a centralized "community" digester that could process manure from area farms, creating power and compost fiber. After 15 years of failed attempts to attract private industry to build the facility, the Port of Tillamook Bay, a local municipal government, secured federal funds to build the nation's first community digester. The Port selected RCM Digesters to design a 2,000-cow plug flow anaerobic digester. The plug flow design was selected based on capitol cost per cow, low operating cost and past performance on individual dairy farms for the past 20 years. The challenge for the Port was to operate on revenues generated from sales of commercial power, compost fiber and liquid nutrient without subsidies from participating dairies in the form of tipping fees. For the past 15 years, tipping fees have been a deterrent in participation from area farmers. The combination of debt service from high capitol costs, large transportation cost and farmers refusal to pay tipping fees has made the project economically non-viable. For a community digester (many farmers sharing a single facility), the single largest expense is the transportation of raw manure to the digester and return of liquid nutrient (effluent) back to the dairy. For 2,000 cows, the monthly movement of both liquids is 1.2 million gallons at a cost of 1 cent/gallon. The goal of the Tillamook digester project is to maximize revenues from power and compost fiber, reduce capitol costs by utilizing grants and facility design and to provide value to the participating farms so operational shortfalls can be offset by tipping fees.

In fiscal years 2000 and 2001, the Port received two earmarks totaling $1,698,000. With a 47% local match, the total project budget was $2,498,000. Construction started July 2002 on a 4,000-cow digester that will be built into two phases, representing 2,000 cows in each phase. After the second earmark was authorized in 2001, the Port double the size of the facility to 4,000-cows but after a "federal haircut" with a 30% reduction the project was phased into 2 parts each representing 2,000-cows. The phasing allowed the Port to construct all the concrete digester tanks, generation building and main electrical infrastructure but needed additional funds to finish the second phase of the project. By November 2003, biogas was operating two caterpillar engine/generator sets with 40,000 gallons of raw manure per day.

Gas volumes and kilowatt-hours per day were 40-50% less than pro-forma's which was attributed to thin manure caused by rainwater. As manure quality improved and gas volumes increased kilowatt-hours increased slightly but gas regulation problems caused serious damage to the engines. Also during this time, main manure pumps failed from seal leaks and fiber separator destroyed several screens and lost plugs, which pumped effluent into fiber truck. All equipment was covered under warranty and was repaired without cost to the project. Continued adjustments were made to all equipment but engines and pumps continued to fail and then repaired. After many fiber separator screens and compressors, the separator started operating correctly producing 80 cuyds/day but at 70% moisture and high ammonia which makes the product value very low.

Transportation was provided by a local tanker company along with Port owned tanker truck, using vacuum pumps for speed. A high vacuum pressure, manure swells causing less volume per tank load increasing the number of total trips per day increasing costs. The continual break downs of equipment, low revenues from power and low value fiber plus the increase in transportation cost required the Port to subsidized the project over $10,000/month. To lower the costs, modifications were made to tanker trucks, biogas engines, manure pumps, solid separator, gas regulators and variety of other poorly functioning components. These modifications did help the project but not to the point which made the project financially viable.

During the first 12 months of operation, the participating dairies started to realize the benefits of the digester. The thinner effluent was easier to handle and field application through traveling irrigators did not plug and were more efficient. Because the solids are removed from the effluent, the liquids were more readily available for plant uptake and grass cutting production doubled or tripled in some cases. The weekly removal of raw manure from the underground parlor tank also provided additional storage and less labor in pumping from the underground to the above ground storage tank, which was being used to receive the effluent. These benefits provided the economic reasons for financial support of the digester operations. To help offset the costs of operations, the participating dairies agreed to pay 80% of the transportation costs till other revenues were generated from the sales of fiber.

The raw manure spends 20 days in the digester at 100 degrees. The temperature and time breaks down cell membranes and destroys a variety of pathogens and diseases. It also breaks down grain, grass and hay fiber into cellulose tubes. These tubes hold water, which can't be removed with the screw press. The uniqueness of this product makes for an excellent soils blend or peat moss substitute if moisture can be reduced below 25%. Several processes were tried to dry the fiber including hydraulic press, windrow turners and a computer controlled static pile air system. The system that has proven to work is a converted saw dust drum drier with a cyclone blower. Modifications have been made to reduce gas volume requirements by operating a gas turbine and using the 900-degree exhaust heat into the drum drier. In order to provide enough gas to operate the engine/generator sets and the gas turbine for drying, cell 3 of phase 2 must be completed.

As of this report, cell 3 is 80% of completion and permanent installation of the gas turbine-drum drier system is also 80% complete. Markets for the finished fiber products have been established with customers impatiently waiting. Once cell 3 is complete and fiber is being successfully sold and generating positive cash, cell 4 or completion of phase 2 will be completed with a third engine/generator set processing manure from over 4,000 dairy cows. By reaching economic viability on both phases, the community digester project will be ready for public or private investment for further expansion to process 100% of the manure from Tillamook's herd of 32,000 dairy cows.

EXPERIMENTAL

The Port selected to build on a concrete foundation which reduced construction costs but caused a challenge in engineering and safe installation of equipment. The typical 1,000 cow plug flow digester is a large rectangle tank 30'x205'x12' built below ground which provides side stability and insulation to an R-19 rating. Because of the high ground water table the Port was forced to build the large rectangle tank above ground on top of an existing concrete slab. The location was the concrete foundation and slab of the remains of the WWII Blimp Hangar A. The location was ideal for all weather construction and provided additional benefits for fiber solids (manure solids removed before effluent is returned for field application) drying and composting.

In October of 2001 the Port received notice of a second earmark to double the size of the facility from 2,000 cows to 4,000 cows. By December of 2001, the earmark was reduced to $750,000 with full cost share of 50%. The challenge was to double the operating capacity with 25% less money and 50% match. From December of 2001 to March 2002, the FONSI (Findings of No Significant Impact) and EA (Environmental Assessment) were issued, DOE (Department of Energy) contracts were modified to allow construction to begin. In April of 2002, bids were received that would allow construction of a 4,000 cow digester that is 120'x205'x12' but would have two phases that would allow operation to expand from 2,000 to 4,000 by adding two additional GenSets (engine/generator equipment). Building permits were issued in May 2002 with construction beginning the first week of July 2002. Construction continued on the digester tanks, utility building and all plumbing and electrical from July through December of 2002.

During the construction the Port worked with State Department of Environmental Quality (DEQ) and Oregon Department of Agriculture (ODA) on necessary permits to operate the facility. This discussion of permits had previously (1995) been agreed between the two parties that ODA would be the permitting agency for the digester operation. Several meetings occurred between the parties in the spring of 2002 with an agreement that would require the digester vessel to be under the authority of DEQ's solid waste permit. ODA would only have authority for the manure and liquid effluent (digested manure returned to farm for field application) and would incorporate the digester operation into the farms animal management plan (CAFO permits). DEQ would also require an air quality permit for the engine generators for emissions. The additional DEQ requirements added to the capitol cost of the digester $30,000 in permit fees, turbo charger modifications and consultants. Annually the DEQ permit requirements and associated fees cost the operation $25,000.

Since March 2002, the Port hosted monthly luncheons with local dairyman to give updates on the digester construction progress and select the participating dairies to start the project. At the first luncheon meeting, over 40 dairymen attended but were very skeptical on whether the project was really going to get built. After 14 years of studies with no facility built, the dairyman "won't believe it till they see it" and will not participant unless the service is free. Each month following, luncheon meetings were held and the number serious farmers narrowed to 9 farms. The 9 farms represented approximately 3,000 milking cows or 75% of the total required to provide manure for the entire project. Since the project was planned to be phased with the start up of 2,000 cows, it was agreed that two of the larger dairies would not be able to participate at 100%. A contract between the Port and dairies was entered into that covered the following components: 1) Dairies provide 11%-13% solids 2) Dairies receive back equal amount of liquid effluent. 3) Dairies provide collection facilities that are accessible to tanker truck 4) Dairies responsible to follow industry standards for disease testing and control 5) Port provide transportation at no cost to and from dairy. 6) Port not liable for the spread of diseases or continued operation if the project is determined to be not economically viable.

By September 2002, the digester concrete tanks were complete and focus turned to generation building, electrical needs and power sale agreements. After many several months of discussion with the Tillamook Public Utility District (TPUD), a letter was provided that outlined the TPUD requirements to sell power directly into the power transmission grid. The requirements were extensive and mainly centered around safety to the TPUD employees and customers. This was a new concept to the RCM digester design since all other digesters built were to provide internal power for the dairy operation. To address the TPUD requirements, the Port had to hirer an electrical engineer to design the system and bid specifications. The extensive requirements became a budgetary problem but was necessary for safe operations of the facility. By March 2003, all plumbing and electrical work was complete along with the Generation building and digester tanks, secondary tanks and associated deck covers. The Power Sales agreement was a critical component to the overall project but the TPUD was extremely slow in making any kind of offer on what they would pay per kilowatt-hour. The Port know the avoidance costs (what the TPUD is currently paying per kilowatt hour) from Bonneville Power Administration BPA was 3.5 cents per kilowatt hour but was led to believe that the TPUD would use our project to launch a Green Tag (environmental attributes of the generated power) program and would pay a higher price for the power. After much discussion, the agreed price was 4.2 cents per kilowatt-hour without the Green Tag, which would still be available for the Port to sell. Bonneville Environmental Foundation (non-profit established by BPA) offered .5 cent per kilowatt-hour on a one-year contract. The combined sells generated 4.7 cents per kilowatt-hour, was a good price for power in the Northwest but 33% less than the Performa that was established during the energy crisis in 2000-01.

By July 2003, modifications were completed to the hauling truck to convert the used sludge tanker to a vacuum system that could quickly remove manure from underground milking parlor tanks to the digester. Transportation is the single largest cost of operation, which would require quick loading and unloading for which a conventional piston pump would not perform. The original tanker truck that was purchased with a 4,000+ gallon capacity tank, which could transport full loads within permit roadway weight limits. Each digester cell requires 20,000 gallons of raw manure each day or 5 round trips. Because the finished liquid effluent returns to the farm, every trip is loaded with either raw or finished. The first Phase of the project with 2 digester cells would require 10 round trips per day with an average round trip length of 50 minutes. The 50 minutes was broken into

10 minutes to load and 10 minutes to unload and 15 minutes travel time. The Performa was based on 10 hours per day, 7 days per week and 1-½ drivers. The digester must be fed (new raw manure added daily) everyday, a backup truck was needed to cover breakdowns, maintenance and other unexpected issues, so the Port contracted with a local hauler that had experience in transporting manure. The local contractor negotiated a rate of $47.50/hour for truck and driver. The contract services would be needed in the startup to fill the digester cells with over 800,000 gallons of manure and then after the Port truck could haul the daily volumes. When the modifications were complete to the Port's truck, the tank volume was reduced by almost 1,000 gallons to accommodate the additional weight of the vacuum pump.

By September 2003, both digester cells were ready for manure along with the engines, controls and hot water systems. The 2-catepillar engines are needed to run to generate heat to warm the bacteria and create the methane gas. The engines must be started on propane gas and run for at least 30 days to heat the manure to approx. 100 degrees (same temperature of a cows stomach) before the gas cover is pulled over the digester cells and sealed to capture the gas and then switched from propane to biogas. Before the raw manure can be added to the startup digester cells, anaerobic bacteria (dairy lagoon sludge) needs to be added first at a rate of 20% or 80,000 gallons per cell or 160,000 gallons total. A dairy lagoon was found and sampled for anaerobic bacteria at the bottom of the lagoon and found to be acceptable. The Port's tanker along with two contract tankers started filling the two-digester cells with approximately 800,000 gallons of raw manure and lagoon sludge and was completed in 5 days. The digester tanks had to be filled within a foot of the wall groves that are used to seal the gasbag to the concrete digester walls. The water-cooled engines were started and hot water started to heat the cool raw manure. The heating process took 40 days and consumed 12,000 gallons of liquid propane. Once the temperatures reached 100 degrees and methane gas bubbles were observed, a floating insulation raft was installed over the digester tanks and the gasbag was pulled over the insulation raft. Since the tanks were elevated 12 feet above ground, this process was extremely dangerous and great precautions had to be taken to insure a safe working environment. Once both covers were pulled the gas bags had to be attached to the concrete walls using a steel angle iron protected with a rubber strip bolted to screw insets in the concrete wall. This was extremely difficult and took several days. Within hours after the gasbag made its final seal the bags filled tight with methane. Once the gasbags were filled, the gas flare started to ignite methane. At this time the gas mixture of methane to carbon monoxide does not support good ratios for operating the engines till the daily process of adding new manure lowers the carbon monoxide levels to less than 40%. This process took 10 days before the engines were switched from propane to methane with the digester project officially burning methane and producing power to the grid the first week of November 2003. Performa's for output rated each engine to run at 150kw, at startup the engines were only able to run at less than 100kw. Performa's for percent solids of manure were between 11%-13% with startup only able to achieve an average of 8%. The high percentage of rainwater in the manure caused less gas, which would account for the poor engine performance. The Port started visiting participating farms and found obvious areas that could be improved to eliminate rainwater into the manure. After a month of operation the percent solid improved and available gas improved but engine performance remained the same. Consultants recommended different gas regulators, which were installed along with advancing the engine timing. These changes did improve performance but caused the engines to compete for gas and would ultimately cause one engine to shut down.

The raw manure spends 20 days in the digester cells before it is forced (by adding new raw manure) over a weir into a secondary tank. From the secondary tank the treated manure (effluent) is pumped into a screw press that removes the solids into a product called digested fiber (fiber). The cellular structure of the fiber holds moisture at the 70 % level with a high ammonia smell. After the effluent is pumped through the screw press the finished effluent (returned effluent) gravity flows into a tank till the vacuum pump truck pulls returned effluent into the truck and back to the dairy's field for land application. The digester consultant specified a large Vincent separator that could handle the volume but had never been used for this application. The separator operates by forming a fiber plug at the end of a screw and then forcing under pressure the liquid through, forcing the fiber out as the screw turns. The stainless steel screens receive tremendous pressures and were wearing large holes within a month period. A variety of screens were tested and the screw press was modified to increase the length of the fiber plug, which removed more liquid from the fiber. Testing on the return effluent found that the digester destroyed 99%+ pathogens, was concentrated in nitrogen and phosphorous and was an excellent liquid fertilizer that enable able dairymen to green chop (cut field grass) their fields two to three times more than raw manure. After several months of operation the challenges of higher operations costs became apparent and needed to be addressed. One of the capital costs of the operation was in the purchase of a vacuum tanker truck. The vacuum pumping was necessary for speed and the difficult locations of underground tanks but the high vacuum pressures caused the fiber in the manure to swell that decreased the volume of manure hauled. This increased the numbers of tanker trips per day and caused a 35% increase in transportation costs. To off set this increase, the size of the tanker had to increase but the physical limitations at the farmer would not accommodate a large tandem axle trailer. Since it would take time and capitol for the farmers to make improvements to accommodate the larger tankers, the decision was made to contract out the services and let private business try to lower operation costs. The Port's tanker truck would be used as backup and to apply directly liquid effluent to farm fields.

After 7 months of operation, the first engine failed when a valve head broke off and destroyed several pistons. The engine was covered under a 1-year warranty, so the supplier absorbed the costs. The system designer and engine provider blamed each other but both agreed that the possible reason was the turbo charger. As stated earlier in this report, the State air quality permits required the engines to have turbo chargers, all other digester engines have been naturally aspirating. The exhaust backpressures created from the turbo chargers caused the values to overheat, break and then mash the tops of the pistons. To prevent this from happening again, temperature gauges were installed and engine timing was reduced to allow more fuel through the engines to keep the values cooler. Shortly after the failed engine was repaired and back on line the second failed with the same problem even after the modifications were made. Again this engine was still under warranty and was repaired. The engine breakdowns had a huge impact on overall efficiency and creditability of the project. With the lowered engine timing, the gas volume per kilowatt-hour was almost doubled to keep the values cool but forced unburned fuel through the engines which is extremely inefficient. The retarded timing, temperature monitoring and monthly value check did not solve the problem, as more failures continued until the engine manufacture acknowledges the problem and redesigned the head that would allow additional cooling. After a year of operation on the new heads, the value wear has been normal with an expected life of 12,000 hours instead of less than 5,000 hours.

Other operational problems were associated with daily feeding of manure into the digester cells. Design called for each digester cell to have a single submersible pump that could pump 12% solids. After several months of operation, the pumps started failing when motor seals failed and manure shorted out the electrical motors. As this problem continued, the manufacture claimed the pumps were not designed for this application and would not warrant future failures. One problem that was identified was that undigested hay balls would plug the pump and cause extreme pressure and heat, which could be a point of failure for the pump seals. The solution to this problem was to place an agitator in the raw manure tank to stir the manure and have the agitator either catch the hay balls or break them up. Future expansion and replacement of the pumping system will remove the electrical component of the pump from the manure through a different design and manufacturer. In addition, the pumping system must be designed to continually pump during a 24-hour period; currently the design system is manual and very labor intensive that requires an operator to turn pumps on and off. This also causes gas production and digester temperatures to decrease after raw manure feedings because large volumes have to added to complete the daily cycle in a 10 hour manned shift. Since the project started burning biogas the series of gas regulars on has been a constant problem and a source of additional labor costs. A variety of different styles and types have been tried but they still require daily adjustments and cause extreme difficultly when first starting the engines. We have determined that the design that combines gas lines from individual digesters cells cause an uneven flow of bio-gas during the peaks and valleys of gas production (due from the uneven raw manure feedings) which cause each engine to "fight" for gas. Eventually one engine will slowly win the battle, reducing the gas flow to the second engine, which will eventually shut down. In order to keep both engines running, the regulators have to be daily adjusted to match the gas flow available. The gas delivery systems needs to be redesigned with each digester cell connected to an engine through a single gas supply line with automatic regulators that adjust when the gas is available.

The goal of the project was to have the generated revenues to cover the costs of operation without charging a tipping fee to the participating diaries. During the first two years of operations, revenues from power sells were approximately 25% of operations costs along with bulk unprocessed fiber sales at 25%. These shortfalls in revenue and increased costs have required the Port to subsidizes the operation at a monthly cost of approximately $10,000 or $240,000 over the two-year period. The best-case scenario for power sales with modifications to the gas and engine systems could increase additional 10% but improvements to digested fiber by drying and marketing could increase revenues to completely cover costs of operation. Funding and designing a fiber drying system along with marketing and packaging would take years and costs between $500,000 to $1,000,000. The Port has completed a marketing plan and researched and developed a drying system that will produce the desired products. Funding for 50% of the fiber drying and packaging system has been secured (Federal earmark 2004) and a small-scale prototype is currently (2005) being built. As financial pressures continue to build from operational losses, the participating dairies in fear of shutdown decided to pay 80% of the transportation costs. The digester has proven to be an asset to the dairy operation with the animal management regulators including the digester in the dairy's permit to operate. Sharing the cost of transportation has greatly helped the financial costs of the operation and would be classified as a tipping fee. Based on the monthly average of transportation for those dairies that have total confined animal operations, the monthly cost per milking cow is $5.25 to use the digester. The Port agreed that as revenues increase from improved digested fiber sales that the tipping fee would be adjusted downward for the current participating dairies but any new dairies would have to continually pay a fee. Contracts with the participating dairies were modified to reflect the change with additional conditions that would allow the digester use to be transferred to a new dairy farm owner if the current participant sells the farm. These changes demonstrate the beneficial use of the digester and the asset it has become for the dairy farm operation. With increase environmental regulation coupled with demonstrated tools in waste management, raw manure on farm fields will become a practice of the past.

RESULTS AND DISCUSSION

Project proforma's based on gas production; power and fiber sales demonstrated a financially viable project that revenues would cover costs. The reality was that revenues were lower than expected and costs were higher, which required the Port and participating dairies to subsidize the operation.

Unrealistic expectations are a common problem for this type of project. The focus is always on the power production side for the major revenue source and not on the secondary products such as fiber. Since all feedlots and animal diets vary, it is difficult to market secondary products until the product is manufactured and test marketed. To introduce a new product in the market place, a niche needs to be identified and product quality needs to be established. Once the Port realized that power revenues would be limited and wet fiber had extremely low values, the goal for the project turned to maximizing fiber revenues by drying and stabilizing the product. The dried fiber product had similar characteristics to peat moss which is a high value product used as a potting soil blend material that helps retain water. The general public has become sensitive to the use of peat moss because it is harvested from wetlands. The "fiber peat" provides a substitute product that uses recycled material, which is an environmental friendly alternative.

Through R&D process, the Port determined that the most cost effective process to dry fiber was using biogas to fire a gas turbine engine. The high airflow and heat is blown through a drum dryer and then sucked through a cyclone that strips off the moisture and ammonia. During an 8-minute pass through the drum dryer the fiber moisture lowers from 70% to 20%-30%. At this moisture content, the fiber product can be packaged in retail bags or simply sold to farmers for bedding. Production is estimated at 10 cubic yards (cuyd) per hour or 80 cubic yards per day. At a moisture content of 20-30%, the fiber can be sold at a minimum value of $7/cuyd for dairy cow bedding, replacing paper pulp and wood chips. The $7/cuyd, generates $15,000/month which is the additional revenue needed to reach a financial break-even point. Bagging the finished fiber product into a retail bag and marketing the product with the "Tillamook" name could increase product value to levels as high as $40/cuyd.

Once optimum product value has been reached and the project demonstrates potential bottom-line profits, private industry should be in a position to build other facilities throughout the County, eventually processing 100% of the raw manure before land application.

CONCLUSION

The Tillamook Digester has been a largest scale research and development demonstration project. Project pro-forma's for capitol costs and revenues were under estimated and over valued. The wet Tillamook climate that has created the need to process raw manure also creates challenges in digester operations and potential outcomes. High operation costs and low product value requires participating dairies to subsidize the operation while secondary product markets are being created.

The project has been successful in demonstrating the substantial removable of pathogens and diseases from raw manure and the beneficial use of liquid effluent for field application. The project has also been successful to point out the realities of constructing and operating similar facilities and possible options to avoid potential problems. In addition, regulatory authorities now realize that the solution is not simple but can be achieved with this type of facility.

The budgetary capitol cost (Federal earmark plus cost share) of the Tillamook Digester in equivalent to a per cow cost of $625. These estimates were low and did not include equipment and facilities necessary to process the secondary fiber products. To build a similar facility for 4,000 dairy cows with 3 engine/generator sets and a gas turbine drum dryer with associated equipment would cost $3 million or $750/cow. These costs represent a public works project, which includes prevail wage rates and other increased associated costs. Financial pro-forma only represents 20% debt service costs, with the bulk of the funding through public grants.

The Tillamook Digester Project only represents 12% of Tillamook's total herd size. In order to process manure from the remaining 28,000 cows, 7-4,000 cow facilities would have to be built at a capitol cost of $21 million. A larger facility might have lower capitol costs but would increase transportation costs. With the projects financial ability to absorbed only 20% of the capitol cost, total grant requirements would be $16.8 million. This investment would process 560,000 gallons/day or 204 million gallons/yr of raw manure into pathogen free effluent, generate 12.6 megawatts of power and dry over 200,000 cubic yards of fiber.

The $16.8 million investment would solve Tillamook's projected power shortage; solve Tillamook's water quality problems and retain/create jobs in this rural- agricultural based community. The Port of Tillamook Bay remains committed to solicit Congress and find the funds to build the needed facilities or help private industry to develop similar facilities.

REFERENCES

MEAD- Methane Energy Agricultural Development

RCM Digester- Resource Conservation Management

Effluent- Digested manure without solids liquid nutrient

Tipping Fees- Fees participating dairies pay to offset costs

Federal Haircut- Program funding reductions

FONSI- Findings of no Significant Impact

DOE- Department of Energy

EA- Environmental Assessment

GenSets- Gas engine and electrical generator

DEQ- Oregon Department of Environmental Quality

ODA- Oregon Department of Agriculture

CAFO- Confined animal feeding operation

TPUD- Tillamook Public Utility District

BPA- Bonneville Power Administration

Green Tag- Environmental attributes

Fight for gas- Engines compete for gas supply

Federal earmarks- Federal grants

R&D- Research and Development

Fiber peat- Digester fiber that has been dried

Federal earmarks plus cost share- Federal grant plus local contribution

Pro-forma's- Estimated project's performance